# BED TEXTURE AND TURBIDITY AS INDICATORS OF FISH BIOTIC INTEGRITY IN THE ETOWAH RIVER SYSTEM

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**Abstract.** We sampled 32 Piedmont streams in the Etowah River system to assess the relationship between fish assemblages, bed texture, and suspended sediments. We also investigated the relationship of sediment regime to basin land cover, basin morphometry, and stream geomorphology. Index of biotic integrity (IBI) scores were positively and more strongly related to stream slope (r = 0.81) than any other single variable. Stream slope and bed texture (mean *phi*) showed strong covariation (r = -0.92), so they could not be analyzed as independent variables. Stream turbidity (NTU) was negatively correlated with IBI scores (r = -0.66), and residual analysis showed that turbidity accounted for a significant amount of the variance ($R^2$ = 0.50) in the slope-IBI regression. Both of these turbidity relationships were nonlinear with an apparent threshold of approximately 10 NTU. Sites averaging higher than 10 NTU consistently had low IBI scores and tended to have the largest negative residuals in the slope-IBI regression.

## INTRODUCTION

The U.S. EPA identified excessive sedimentation as a leading component of nonpoint source pollution in the United States (U.S. EPA 1990) and estimated that 45% of U.S. streams are impacted by sediment. The negative effects of sediment on fishes include reduced feeding success, reduction in the food base due to lower secondary production, loss of spawning habitat, and reduced spawning success (reviewed in Waters 1995). The majority of the research reviewed targeted salmonid species in relatively low diversity streams of the western U.S.

Recent research has focused on sediment and fish relationships in more diverse Southeastern streams. Meyer et al. (1999) documented the negative impact of stream turbidity in species rich Blue Ridge streams, and Walser and Bart (2000) showed the effects of excess bed sediment on stream fish assemblages in the Fall Line region of the Chattahoochee River system. There is little published information on the effects of sediment on fishes in the Piedmont physiographic province or linkages between human disturbance and sediment regimes of Piedmont streams.

We investigated the impact of sedimentation on fishes in Piedmont tributaries of the Etowah River system. The Etowah supports a diverse assemblage of species and is influenced by a rapidly urbanizing landscape. Our goals were to identify correlative relationships between stream sediment and fish assemblages and to identify linkages between sediment regime and stream geomorphology, basin morphometry, and watershed land use. Fish assemblages were assessed using an Index of Biotic Integrity (IBI) modified for the Etowah River system fishes.

## METHODS

In 1999 we surveyed 30 Piedmont streams in the Etowah River system. One of theses streams was removed from the final analysis because beavers dammed the site during the study. Two additional sites were sampled in 2000 (final n = 31). Detailed site descriptions are in Leigh et al. (these proceedings).

We evaluated suspended sediment by measuring turbidity (NTU) and total suspended sediment (TSS). Suspended sediment was measured at baseflow and values used for analysis were based on a mean of six samples for NTU and 3 samples for TSS. Bed texture was evaluated based on visual counts and particle analysis of sieved samples. Stream slope was measured over the survey reach with an electronic total station. Fishes were sampled during summer baseflows using a backpack electrofisher, seine, and dipnet. Reach length

**Table 1. Metrics modified from Karr et al. (1986).**

| Etowah River System IBI Metrics |
|---|
| **Species richness and composition** |
| Richness |
| Proportion of darter and sculpin species |
| Proportion of centrarchid species |
| Relative abundance of tolerant taxa |
| **Trophic composition** |
| Proportion of insectivorous cyprinid species |
| **Fish abundance and condition** |
| Density (fish/$m^2$) |

was scaled to approximately 40 times mean baseflow stream width (Angermeier and Smogor 1995). All habitats were sampled in a single pass using a combination of shocking and seining.

We calculated an Index of Biotic Integrity (IBI) following Karr et al. (1986) to compare fish assemblages among sites (Table 1). The IBI proposed by Karr et al. (1986) assigned scores based on high quality, regional reference sites. Instead of comparing our samples to reference sites, we scored the metrics based on percentiles calculated from all 31 sites. This method generated an index of relative integrity that may lack regionally applicability but is a suitable tool for making comparisons among sites (Shields et al. 1995).

Our metric scoring criteria followed Karr et al. (1986) except for the proportion of centrarchid species. Karr et al. (1986) viewed sunfish diversity as a positive indicator of quality pool habitat in Midwestern streams. However, we concur with published studies (Meyer et al. 1999, Walser et al. 1999) that document a positive correlation between centrarchids and increasing levels of disturbance. More detailed information on metric selection and scoring is available in Walters (dissertation in progress). Final IBI scores were scaled to 100.

Land cover data were based on *Landsat* TM scenes for 1987 and 1997 (Lo and Yang 2000). The % urbanized category represents the proportion of the watershed converted to urban land use from 1987-1997. Likewise, the % deforestation represents the total loss of tree cover over the same period.

Basin area, total relief, and local relief were calculated from 1:24000 digital topographic maps. Total relief is the total elevation range of the watershed and local relief is the elevation range in the vicinity of the stream.

We used correlation analysis to assess the relationship between bed texture, suspended sediment, total IBI score and metrics (Table 2). The metric density was not included in this analysis because it was correlated with watershed area.

## RESULTS

Of the bed texture variables, % fines in riffles and mean *phi* were the best predictors and were negatively correlated with IBI score. The *phi* scale is based on $-\log_2$ of the intermediate diameter of stream particles and uses values ranging from –12 to 12. Because it employs a negative logarithm, larger particles have smaller *phi*. Thus, negative correlations between *phi* and IBI indicate that IBI increases with increasing particle size. The % silt/clay in riffles poorly predicted IBI and most metrics.

NTU and TSS were negatively correlated with IBI score and were significantly correlated with all of the component metrics (Table 2). NTU and TSS showed the same trends, but TSS tended to have stronger correlations. The predictive power of NTU

**Table 2. Correlations between IBI score, IBI metrics, and stream sediment parameters. Bed texture, n = 31 sites; suspended sediment, n = 29 sites. Significance levels: [a] = $p < 0.05$; [b] = $p < 0.01$; [c] = $p < 0.001$. [1] Variables based on sieve data; [2] variables based on visual counts.**

| | Bed texture | | | | Suspended sediment | | |
|---|---|---|---|---|---|---|---|
| | % fines in riffles[1] | % silt/clay in riffles[1] | Average *phi* in pools[1] | Standard deviation *phi*[2] | Mean phi[2] | NTU | TSS |
| IBI score | -0.77[c] | 0.14 | -0.68[c] | 0.56[b] | -0.79[c] | -0.66[c] | -0.84[c] |
| **Metrics** | | | | | | | |
| Rank Richness | -0.49[b] | 0.13 | -0.35 | 0.34 | -0.50[b] | -0.48[b] | -0.66[c] |
| Prop. insectivorous cyprinid spp. | -0.53[b] | -0.07 | -0.33 | 0.45[b] | -0.47[b] | -0.50[b] | -0.54[b] |
| Prop. centrarchid spp. | 0.53[b] | 0.17 | 0.51[b] | -0.39[a] | 0.59[c] | 0.66[c] | 0.65[c] |
| Prop. darter and sculpin spp. | -0.66[c] | 0.41[b] | -0.57[c] | 0.54[b] | -0.79[c] | -0.54[b] | -0.66[c] |
| Relative abundance tolerant spp. | 0.59[c] | -0.24 | 0.69[c] | -0.43[b] | 0.71[c] | 0.67[c] | 0.65[c] |

Table 3. **Correlations between stream sediment and selected variables. Mean *phi*, n = 31 sites; NTU, n = 29 sites. Significance levels: [a] = $p < 0.05$; [b] = $p < 0.01$; [c] = $p < 0.001$.**

| | Mean *phi* | NTU |
|---|---|---|
| **Basin Morphometry** | | |
| Basin Area | 0.27 | -0.13 |
| Total Relief | -0.45 [b] | -0.52 [b] |
| Local Relief | -0.22 | -0.50 [b] |
| **Stream Geomorphology** | | |
| Slope (EGL) | -0.92 [c] | -0.41 [a] |
| **Land Cover** | | |
| 1987-97 % Urbanized | 0.47 [b] | 0.31 |
| 1987-97 % Deforested | 0.16 | 0.28 |
| 1997 % Agriculture | 0.19 | 0.53 [b] |
| 1997 % Forest | -0.38 [a] | -0.52 [b] |
| 1997 % Urban | 0.37 [a] | 0.31 |

and TSS was comparable to mean *phi* and % fines in riffles, but the suspended sediment variables were better predictors of richness and the proportion of insectivorous cyprinids.

The trends identified by the bed texture variables were the same as those for suspended sediment variables. Those variables that declined along with decreasing bed particle size (e.g. the proportion of darter and sculpin species) also declined with increasing suspended sediment.

Mean *phi* and NTU were used to investigate the larger scale processes influencing sediment regime (Table 3). Stream slope was negatively correlated with mean *phi* (r = -0.92). Because stream slope largely determines bedload size, (Knighton 1984) we treated it as the primary variable linked to biotic integrity. As with bed texture, IBI score was correlated with stream slope (Figure 1). Total relief also correlated with mean *phi* and was a better predictor than any of the land cover variables.

Total and local relief negatively correlated with NTU (Table 3) indicating that clearer streams drain the steepest watersheds. The strongest land cover predictors were the % forest cover and % agriculture cover. NTU increased with agriculture and decreased with forest cover. The % urban land cover and % urbanized between 1987-97 were not significantly correlated with NTU.

A plot of the NTU data shows a linear decline in IBI scores to around 10 NTU (Figure 2a). At mean baseflow turbidity over 10 NTU, IBI scores level off and never exceed 40. To normalize for the effects of slope, we plotted the same NTU data against the residuals from the slope-IBI regression (Figure2b). Sites with high baseflow turbidity were the largest negative residuals in the slope-IBI model and had consistently low IBI scores. As in figure 2a, the decline is linear to around 10 NTU then levels off.

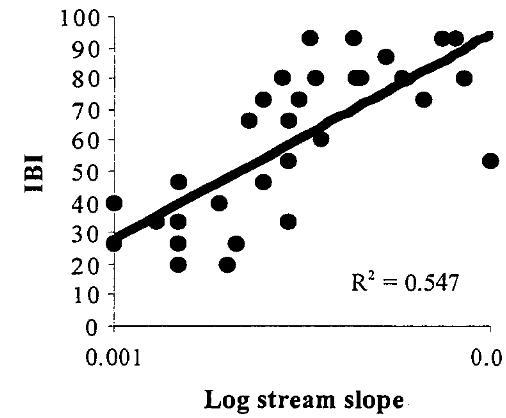


**Figure 1. IBI and stream slope.**

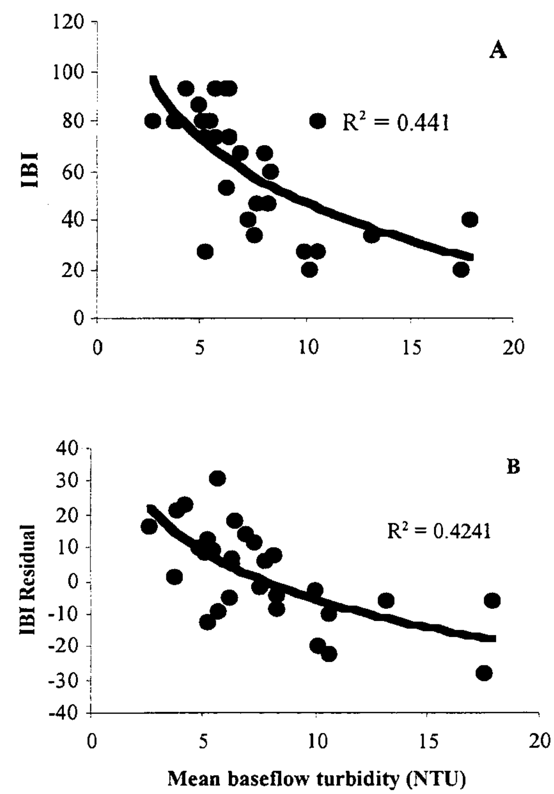


**Figure 2. Regression of (A) NTU and IBI score and (B) NTU versus residuals from the slope-IBI model in Fig. 1.**

## DISCUSSION

Bed texture and suspended sediment were correlated with IBI scores in our study streams. IBI scores decreased with decreasing mean particle size and with increasing turbidity. Declines in IBI were associated with reduced richness and density as well as fewer darter, sculpin, and insectivorous cyprinid species. As these taxa declined, tolerant taxa and centrarchid species increased.

Because stream slope and bed texture covaried, their influence on IBI scores could not be analyzed separately. This covariation also confounded the influence of land cover on bed texture. Slope appears to be a "natural" environmental factor structuring fish assemblages through its interaction with land use. High slope sites can export human derived sediment inputs while low slope sites store the sediment on the channel bed. Thus, high slope sites may be more resilient to current and historic sediment inputs.

Testing this hypothesis is difficult because land use, stream slope, and basin morphometry are correlated to some extent. We observed that streams draining steep watersheds carry larger bed material and have lower turbidity. Most land disturbing activities (e.g. agriculture and urban development) are concentrated in the southern portion of the watershed just north of the Atlanta metropolitan area. These catchments had low total relief and low slope streams. High slope streams in high relief catchments tend to have a larger proportion of forest cover and higher IBI scores.

Even after accounting for the strong influence of slope on IBI score, it is clear that turbidity has a negative impact on fishes. Meyer et al. (1999) showed significant differences in Blue Ridge fish assemblages at baseflow turbidities between 10 and 15 NTU. Our results indicate that linear declines in biotic integrity begin even lower, around 5 NTU. At NTU levels > 10 biotic integrity scores are consistently low. These data indicate that a significant negative impact to fish assemblages occurs in streams with low levels of baseflow turbidity.

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